Development of Chinese orthographic processing: A cross-cultural perspective

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To cite this article: Yang C. Luo, Xi Chen, S. Hélène Deacon & Hong Li (2011) Development of Chinese orthographic processing: A cross-cultural perspective, Writing Systems Research, 3:1, 69-86, DOI: 10.1093/wsr/wsr008

To link to this article: http://dx.doi.org/10.1093/wsr/wsr008

Published online: 20 Dec 2011.

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Development of Chinese orthographic processing: A cross-cultural perspective

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Abstract
This study investigated young Chinese children’s development of orthographic processing and the factors that contribute to development. The investigation was carried out in both China and Canada to examine the effect of language learning contexts on the development of orthographic processing. Participants were ninety-four kindergarten and Grade 1 children in the Mainland of the People's Republic of China (PRC) and ninety-one kindergarten and Grade 1 Canadian-Chinese children in Canada. Children received a battery of measures twice roughly 1 year apart, including Chinese and English orthographic discrimination, radical position awareness, phonological awareness (syllable and phonemic awareness), character reading, and rapid digit naming. Children's home print exposure was measured by a questionnaire at the onset of the study. In both countries, children were able to differentiate between Chinese and English orthographic units at the beginning of kindergarten. Children in China, however, developed more advanced radical position awareness than their counterparts in Canada. Moreover, different factors contributed to individual differences in Chinese orthographic processing in different learning environments. In China, the phonological awareness and character reading measures significantly predicted radical position awareness, whereas in Canada, home print exposure was the most consistent predictor across different testing times. The differences observed between the two groups of children underscore the impact of language learning environment on the development of orthographic processing.

Writing systems reflect a set of principles that define basic orthographic units of the systems and how they map onto language units (Perfetti et al., 2007). Different writing systems may utilize different design principles, and may impose different cognitive demands on literacy acquisition of respective languages (Perfetti et al., 2002). Learning to read is to understand these principles, and to process and comprehend written texts. Clearly, learning to read Chinese imposes a high cognitive demand...
on orthographic processing because the smallest orthographic unit, the stroke, does not convey any sound information, and therefore Chinese characters cannot be sounded out through a systematic orthography-to-phonology mapping as in alphabetic writing systems. Research has suggested that orthographic processing plays a crucial role in reading Chinese (e.g. Ho et al., 2002; Ho et al., 2004; McBride-Chang and Ho, 2005; Ho et al., 2007; Keung and Ho, 2009). However, no previous studies have explored the factors that contribute to the development of Chinese orthographic processing. The present study examined the development of orthographic processing in Chinese children in kindergarten and Grade 1 and the factors that contribute to children's orthographic development. Additionally, we evaluated the effect of language learning environment on such development by comparing Chinese children in China and Canadian–Chinese children in Canada.

1 Development of Orthographic Processing in Chinese

The term orthography refers to conventions used in a writing system to represent the sound of a language (Treiman and Cassar, 1997). Orthographic processing involves ‘memory for specific visual/spelling patterns that identify individual words, or word parts, on the printed page’ (Barker et al., 1992, pp. 335–36). For example, in English, -ilk is a legal letter pattern that appears at the end of words, e.g. milk and silk, while –ilv is an illegal letter pattern that never exists at the ends of words in English.

Chinese is a writing system composed of thousands of characters (e.g. 由 and 江). The smallest orthographic unit in Chinese is the stroke (e.g. 丶 and 丿). Unlike letters in alphabetic writing systems, a stroke does not have either pronunciation or meaning. Strokes combine to form radicals, which are important functional units (e.g. Peng et al., 1997; Shu and Anderson, 1999). About 80–90% of characters in modern Chinese are semantic–phonetic compounds. Most semantic–phonetic compound characters consist of one semantic radical and one phonetic radical in either a left–right or top–bottom structure (Shu et al., 2003). It is estimated that 200 semantic radicals and 800 phonetic radicals exist in modern Chinese (Hoosain, 1991). The semantic radical indicates the meaning of the character, while the phonetic radical represents the pronunciation, although the representation is not always reliable. For example, the semantic–phonetic compound character, 晴 qing1, consists of one semantic radical 氵 on the left, meaning ‘water’, and one phonetic radical 青 qing1 on the right, suggesting the pronunciation qing1. In 花 hua1, the semantic radical 花 appears on the top meaning ‘herb’, and the phonetic radical 化 hua4 appears at the bottom partially suggesting the sound of the character. Generally speaking, semantic radicals tend to appear on the left or top positions and phonetic radicals on the right or bottom positions, though exceptions do exist.

In the present study, we focused on two aspects of orthographic processing. The first aspect is the basic understanding of orthographic units in a given writing system (Geva and Willows, 1994). For example, children with basic understanding of Chinese and English orthographic units should be able to distinguish between Chinese strokes and English letters, e.g. 丶 versus L. Research has shown that children in an English-speaking environment can differentiate between written Chinese and written English as young as in preschool, though they may not be able to tell Russian and English apart at this age (Geva and Willows, 1994). This is due to the fact that the differences between the Chinese and English writing are more salient than those between Russian and English. Based on this finding, we predicted that the children involved in our study would be able to differentiate between English and Chinese even in kindergarten.

In addition to Chinese–English orthographic discrimination, we examined radical position awareness, an aspect of orthographic processing that is specific to Chinese (Chan and Nunes, 1998; Shu and Anderson, 1999; Ho et al., 2002, 2003a, 2004, 2007; Wang et al., 2003, 2004). Radical position awareness refers to positional regularity of radicals in forming compound characters. As previously noted, semantic radicals usually occupy the left or top position of a character while the positions of phonetic
Development of Chinese orthographic processing

The ‘water’ radical, only appears on the left side of a character, such as in 江 ‘river’ and 洗 ‘wash’. An ill-positioned radical leads to an illegal character configuration.

Several cross-sectional studies have examined the development of radical position awareness in children. The results of these studies suggest that children start to acquire insight into radical positions early, around Grade 1 (Chan and Nunes, 1998; Shu and Anderson, 1999). Chan and Nunes (1998) examined radical position awareness among Hong Kong children from kindergarten to Grade 3 with a lexical decision task, which consisted of pseudocharacters with radicals in legal positions and non-characters with radicals in illegal positions. Grade 1 children were able to make some correct choices. However, it was not until Grade 3 that children were able to reject the majority of non-characters and accept the majority of pseudocharacters. In another study, Shu and Anderson (1999) tested radical position awareness among children in Grades 1, 2, 4, and 6 in Beijing. They found that even Grade 1 children were able to correctly reject >90% of non-characters with radicals in illegal positions as unacceptable and children in Grade 2 or higher achieved over 95% correctness. Taken together, both studies suggest that Chinese children begin to develop sensitivity to radical positions around Grade 1.

2 Factors Predicting Orthographic Processing

Since we are not aware of any previous studies that have investigated the factors that affect Chinese orthographic processing, our review of the literature here is based on research conducted in alphabetic writing systems. This body of research suggests that three factors may contribute to individual differences in orthographic processing. The first and most salient factor is print exposure, in that orthographic processing is a print-based skill, and repeated exposure to a specific orthographic pattern increases the stability of orthographic representation (Stanovich and West, 1989; Kirby et al., 2008).

Print exposure is often measured with questionnaires or title/author/magazine recognition tests (Stanovich and West, 1989; Cunningham and Stanovich, 1990; Stanovich et al., 1991), and has been found to be a significant predictor of orthographic processing over and above phonological skills in both adult and young readers of English (Stanovich and West, 1989; Cunningham and Stanovich, 1990; Stanovich et al., 1991). We expected to see a similar association between print exposure and orthographic processing in Chinese in this study.

The second factor is phonological skills. In alphabetic reading, orthographic processing is closely associated with phonological processing because orthographic units map systematically onto phonological units in the spoken language (e.g. Stanovich and West, 1989; Cunningham and Stanovich 1990; Stanovich et al., 1991; Barker et al., 1992; Olson et al., 1994; Cunningham et al., 2001; Gayán and Olson, 2001). In fact, there likely exists a reciprocal relationship between phonological processing and orthographic processing, as the development of one facilitates the other (Sprenger-Charolles et al., 2003). Phonological awareness is a spoken language skill that emerges from experience with the oral language. It has been observed in children as young as 3-year-olds (e.g. Metsala, 1999; Shu et al., 2008). Orthographic processing, on the other hand, is a print-based skill that develops hand in hand with reading experience. Since some aspects of phonological awareness such as syllable awareness usually develop before orthographic processing, in the present study, we conceptualize the former as a predictor of the latter. However, phonological and orthographic processing may be less closely related in Chinese than in alphabetic languages/writing systems because the correspondence between phonology and orthography is less systematic.

The third factor that contributes to orthographic processing is reading ability. Orthographic processing is usually considered as a predictor of reading. Nonetheless, it is likely that orthographic skills and reading ability are reciprocally related. That is, orthographic sensitivity contributes to word learning, which in return strengthens orthographic representation. Previous literature has primarily
focused on the prediction of orthographic processing to reading outcome, and rarely tested the relationship in the reverse direction (e.g. Conners and Olson, 1990; Cunningham and Stanovich, 1990; Holmes, 1996). More recently, some researchers have pinpointed the importance of accumulative reading experiences in the acquisition of orthographic representation (Ehri, 2005; Castles and Nation, 2006). Acknowledging that a similar bi-directional relationship between orthographic processing and reading may exist in Chinese, in the present study, we were particularly interested in the role that Chinese reading plays in the development of orthographic processing.

3 Learning to Read Chinese in the Mainland of the People's Republic of China and in Canada

Another objective of the present study was to explore how orthographic processing develops in different Chinese-learning contexts, i.e. China versus Canada. In recent years, more and more Chinese children learn to read Chinese in Canada where Chinese is not the societal language. However, little is known about how children develop Chinese reading skills in this environment, despite the fact that Chinese is the third most spoken language in Canada, next only to the two official languages, English and French (Statistics Canada, 2006). Comparing Chinese literacy development between Chinese children in these two countries sheds light on Chinese reading acquisition in different cultural and language learning contexts, and provides theoretical guidance for Chinese instruction in non-Chinese-speaking countries.

Children in China and Canada differ in the amount of exposure to spoken and written Chinese. In China, Chinese is the primary language used at home and the language of school instruction. In Canada, children of Chinese descent learn English at school, but use Chinese at home with their parents. Since junior kindergarten, Canadian–Chinese children may also receive 2.5-h Chinese instruction each week in heritage language programs. However, there is no standard curriculum guiding Chinese language teaching and learning in the Canadian context. Due to a lack of Chinese exposure in school, literacy practice at home may be more critical for Chinese learning and maintenance (Xiao, 1998). Since language learning contexts are important for children's literacy development, children in different contexts may follow different developmental trajectories (Bialystok, 1996). In the present study, we compared similarities and differences in how Chinese children and Canadian–Chinese children acquire orthographic skills.

4 Overview of the Present Study

The present study had three aims. First, we examined whether children develop different aspects of orthographic processing, including Chinese–English orthographic discrimination and radical position awareness, in early reading acquisition. Second, we studied the contribution of three factors, home print exposure, phonological awareness, and character reading, to Chinese orthographic processing. Finally, we explored the impact of linguistic environment. That is, we attempted to identify the similarities and differences in the developmental patterns concerning Chinese orthographic processing, as well as in the factors that contribute to these patterns, in China and Canada.

Our sample consisted of Mandarin-speaking kindergarten and Grade 1 children in Beijing, China, and Toronto, Canada. They were tested at the beginning and end of the academic year on Chinese–English orthographic discrimination and radical position awareness. They also received measures of character reading, phonological awareness, and rapid digit naming. Their home print exposure was evaluated through a parent questionnaire. To our knowledge, this was the first longitudinal study that investigated the development of orthographic processing in Chinese children, as all previous studies (e.g. Chan and Nunes, 1998; Shu and Anderson, 1999; Ho et al., 2003a,b) were cross-sectional in nature.
5 Method

5.1 Participants

The present investigation was a 1-year longitudinal study. Children were tested at the beginning of the study and again at the end, roughly 1 year apart. There were 187 typically developing Chinese children at Time 1, including forty-eight kindergarten children ($M_{age} = 5.66\text{ years}, SD = 0.52\text{ years}; \text{twenty-five females}$) and forty-five Grade 1 children ($M_{age} = 6.72\text{ years}, SD = 0.38\text{ years}; \text{twenty-four females}$) from an elementary school in Beijing, China, and fifty-six kindergarten children ($M_{age} = 5.23\text{ years}, SD = 0.53\text{ years}; \text{twenty-five females}$) and thirty-five Grade 1 children ($M_{age} = 6.58\text{ years}, SD = 0.33\text{ years}; \text{twelve females}$) from Chinese heritage language programs in Toronto, Canada. All children participated as part of a larger cross-cultural literacy project. At Time 2, thirty-seven kindergarten children and forty-two Grade 1 children in China and forty-one kindergarten children and twenty-four Grade 1 children in Canada remained in the study. The Canadian–Chinese children were of Chinese descent with both parents born in China. Sixty-two percent of them were born in Canada, and the other 38% were born in a Chinese-speaking country or region, e.g. the Mainland of People’s Republic of China (PRC), Taiwan, and Singapore, and moved to Canada at an average age of 3 years and 5 months.

For the children in China, Mandarin Chinese was the language spoken at home and the language of instruction at school. In Canada, the children were exposed to Mandarin Chinese mainly at home. The parents of the Canadian–Chinese children in our sample reported that 80% of these children spoke Chinese at home most of the time, and >85% of the parents mostly used Chinese with their children. The Canadian–Chinese children also received Chinese instruction for 2.5h every week in heritage language classes. These children received English instruction in public schools. Both groups of children learned pinyin, an alphabetic transliteration system used to transcribe character pronunciation, and the simplified Chinese writing system in their school or heritage language program. Average parent education level was high school for the Chinese children and university for the Canadian–Chinese children.

5.2 Measures

The participants in China were tested at the beginning of the fall semester and again at the end of the spring semester. The timeline was slightly different for the children in Canada due to the limited testing time allowed during heritage language classes. They were tested during the fall semester of the first academic year and the fall semester of the second academic year. The children received radical position awareness, rapid digit naming, phonological awareness, and character reading at both testing times. They received nonverbal reasoning and Chinese–English orthographic discrimination at Time 1 only. At Time 1, the parents of the participating children filled out a family literacy questionnaire, in which they responded to questions regarding their child’s immigration experience, Chinese language use, and print exposure at home.

5.2.1 Nonverbal reasoning

Nonverbal reasoning was measured with the Raven Standard Progressive Matrices (Raven, 1958). The measure comprises five sets of twelve items each, in an order of increasing difficulty. Only the first three sets were used in the present study provided that our participants were still at the lowest age range the test was intended for. The reliability of the measure was Cronbach’s $\alpha=0.83$.

5.2.2 Rapid digit naming

This test was adapted from the Rapid Digit Naming subtest of the Comprehensive Tests of Phonological Processing (CTOPP, Wagner et al., 1999). Thirty-six digits, composed of 2–5, 7, 8, were listed randomly on a letter size paper. The child was asked to name these digits one by one as fast as they could in Chinese. The testing and scoring procedure of the original standardized test was followed.

5.2.3 Chinese phonological awareness

Chinese phonological awareness was assessed with a deletion task containing syllable and phoneme deletion items. The child was requested to delete
a syllable from a multiple-syllable word, or an initial, middle, or end phoneme from a syllable. Both real and pseudo word items were used. For example, children were asked to delete mian4 from mian4-bao1, and to delete s from se4. The task contained four practice items and twelve syllable deletion and twelve phoneme deletion test items. The Cronbach’s α reliability was 0.93 and 0.94 for Times 1 and 2 respectively.

5.2.4 Character reading
This task consisted of 125 unrelated characters, selected from the twelve volumes of the Elementary School Textbooks (1996) employed in the Chinese language curricula in the Mainland of the PRC. It started with highly frequent characters (e.g. 人 ‘person’, 小 ‘small’) and moved to less frequent ones (e.g. 蹦 ‘slink’, 黝 ‘swarthy’). The test was discontinued when the child misread 10 characters consecutively. The total number of correctly read characters was recorded as the character reading score. The Cronbach’s α reliability was 0.98 and 0.98 for Times 1 and 2, respectively.

5.2.5 Chinese–English orthographic discrimination
This task assessed the ability to distinguish between Chinese and English orthographic units. Each item consisted of a pair of stimuli, one of which was a Chinese stroke and the other was an English letter, (e.g. 丷 and f). The child was asked to judge which one was a Chinese stroke. The task comprised two practice and twelve test items. The Cronbach’s α reliability was 0.82.

5.2.6 Radical position awareness
This task assessed awareness of legal positions of Chinese radicals. Each item included a pair of pseudo characters, contrasting one with its components in legal positions (e.g. 碤) and the other with its components in illegal positions (e.g. 舁, the radical 丷 can only appear on the left side of a character). The child was asked to indicate which of the two pseudocharacters looked more like a real Chinese character. The task contained two practice and twelve experimental items. The Cronbach’s reliability was 0.59 and 0.71 for Times 1 and 2, respectively.

5.2.7 Chinese print exposure at home
In the family questionnaire, two questions explicitly requested information regarding the child’s Chinese print exposure at home. The first question asked how often the child read Chinese at home on a five-point likert scale (‘never’, ‘2h per week’, ‘2–5h per week’, ‘1–2h per day’, and ‘>2h per day’). The second question asked the number of Chinese books at home, also on a five-point likert scale (‘0’, ‘0–20’, ‘21–40’, ‘41–60’, and ‘>60’). The parents’ responses to the two questions were added together and used as an index for Chinese print exposure at home.

5.3 Procedure
Testing occurred in a quiet location in the participant’s school or heritage language class. Nonverbal reasoning, rapid digit naming, and phonological awareness were administered in one testing session. The orthographic processing tasks and character reading were given in the other session. Testing was counterbalanced within and between sessions. Experimenters were trained graduate students in psychology who were native speakers of Mandarin Chinese.

6 Results
The original data set contained missing values due to attribution (e.g. participants moved out of the area) from Time 1 to Time 2 and absence at each testing session. Approximately 14% of the values were missing in the children in China, and 15% of the values were missing in the children in Canada. We performed Little’s MCAR test and found that missingness was at random for both groups of children, $\chi^2(227)=23.308$, $p=.28$, and $\chi^2(1333)=1298.561$, $p=.75$, respectively. The effect of missingness of each variable on other variables was subsequently examined with $t$-tests. None of the $t$-tests was significant, $ts\leq 2.0$, $ps\geq .07$ for the Chinese children, and $ts\leq 1.6$, $ps\geq .12$ for the Canadian–Chinese children, hence confirming the missing completely at random assumption. We imputed data using the SPSS multiple imputation function, and synthesized the results based on the suggestion made by Rubin (1987) and Schafer (1997). The results based on the imputed data remained the same as those on
the original data. In this section, we report the synthesized results based on the imputed data.

Means and SDs of the variables are reported in Table 1. Raw scores are presented for all the measures. For phonological awareness, both composite scores and scores of syllable awareness and phonemic awareness are reported. The composite score of Chinese reading frequency and Chinese books at home was used as an index of home print exposure to Chinese. Both composite scores and sub-scores are displayed. Generally speaking, the Chinese children performed better than the Canadian–Chinese children on most measures and both groups improved from Time 1 to Time 2.

With respect to phonological awareness, the children in both countries clearly demonstrated syllable awareness in kindergarten and Grade 1. While the Chinese kindergarten children had a very low level of phonemic awareness, the Grade 1 children's phonemic awareness was much higher, $F(1, 91)=440.22, p<.001, \eta^2_p=0.83$. This dramatic improvement from kindergarten to Grade 1 can be attributed to the pinyin instruction offered at the beginning of Grade 1. Because pinyin is a shallow alphabetic system with regular letter sound correspondences, pinyin instruction has been shown to facilitate phonemic awareness in Chinese children (e.g. Leong et al., 2005). The Canadian–Chinese kindergarten children already had rudimentary phonemic awareness at Time 1 and their level improved greatly from Time 1 to Time 2, $F(1, 89)=21.72, p<.001, \eta^2_p=0.20$. Compared to the Chinese children, the Canadian–Chinese children's higher level of phonemic awareness in kindergarten, $F(1, 102)=115.81, p<.001, \eta^2_p=0.53$, is likely due to the fact that phoneme is more salient in English than in Chinese.

The Chinese and Canadian–Chinese children had different amounts of exposure to Chinese. The Chinese children read Chinese for about 1–2 h every day, while the Canadian–Chinese children read

<table>
<thead>
<tr>
<th>Measures</th>
<th>Min–Max</th>
<th>Kindergarten</th>
<th>Grade 1</th>
<th>Kindergarten</th>
<th>Grade 1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Time 1 (T1)</td>
<td>Mean (SD)</td>
<td>Time 2 (T2)</td>
<td>Mean (SD)</td>
</tr>
<tr>
<td>Nonverbal reasoning</td>
<td>0–36</td>
<td>14.81 (3.94)</td>
<td>19.07 (5.88)</td>
<td>14.82 (3.71)</td>
<td>21.82 (6.01)</td>
</tr>
<tr>
<td>T1 rapid digit naming</td>
<td>NA</td>
<td>69.52 (17.64)</td>
<td>47.35 (11.06)</td>
<td>91.50 (72.49)</td>
<td>65.17 (53.11)</td>
</tr>
<tr>
<td>T1 phonological awareness</td>
<td>0–24</td>
<td>9.19 (3.51)</td>
<td>18.31 (3.94)</td>
<td>10.11 (7.53)</td>
<td>17.89 (5.79)</td>
</tr>
<tr>
<td>T1 syllable awareness</td>
<td>0–12</td>
<td>8.33 (3.70)</td>
<td>10.31 (2.63)</td>
<td>6.16 (5.14)</td>
<td>9.49 (4.50)</td>
</tr>
<tr>
<td>T1 phonemic awareness</td>
<td>0–12</td>
<td>0.87 (2.38)</td>
<td>8.00 (3.88)</td>
<td>3.95 (5.61)</td>
<td>8.40 (6.77)</td>
</tr>
<tr>
<td>T1 Home print exposure</td>
<td>2–10</td>
<td>7.88 (1.38)</td>
<td>6.93 (1.49)</td>
<td>4.47 (1.54)</td>
<td>5.00 (1.76)</td>
</tr>
<tr>
<td>Chinese reading frequency</td>
<td>1–5</td>
<td>4.70 (0.69)</td>
<td>4.20 (1.16)</td>
<td>1.92 (1.05)</td>
<td>2.43 (1.17)</td>
</tr>
<tr>
<td>Chinese book at home</td>
<td>1–5</td>
<td>3.12 (1.15)</td>
<td>2.68 (1.01)</td>
<td>2.50 (0.95)</td>
<td>2.52 (0.87)</td>
</tr>
<tr>
<td>T1 Character reading</td>
<td>0–125</td>
<td>30.92 (19.82)</td>
<td>54.96 (17.03)</td>
<td>16.70 (17.06)</td>
<td>29.66 (19.09)</td>
</tr>
<tr>
<td>T1 Orthographic discrimination</td>
<td>0–12</td>
<td>11.40 (1.19)</td>
<td>11.24 (1.64)</td>
<td>11.38 (1.87)</td>
<td>11.56 (1.11)</td>
</tr>
<tr>
<td>T1 Radical position awareness</td>
<td>0–12</td>
<td>8.02 (2.28)</td>
<td>9.47 (2.55)</td>
<td>6.39 (1.66)</td>
<td>8.12 (1.90)</td>
</tr>
<tr>
<td>T2 Rapid digit naming</td>
<td>NA</td>
<td>58.42 (14.49)</td>
<td>40.09 (8.88)</td>
<td>58.50 (23.94)</td>
<td>47.68 (13.59)</td>
</tr>
<tr>
<td>T2 Phonological awareness</td>
<td>0–24</td>
<td>9.49 (2.67)</td>
<td>19.31 (2.82)</td>
<td>16.74 (4.90)</td>
<td>20.79 (4.20)</td>
</tr>
<tr>
<td>T2 Syllable awareness</td>
<td>0–12</td>
<td>8.67 (3.54)</td>
<td>10.42 (1.93)</td>
<td>8.49 (3.91)</td>
<td>9.74 (4.95)</td>
</tr>
<tr>
<td>T2 Phonemic awareness</td>
<td>0–12</td>
<td>0.89 (2.06)</td>
<td>8.83 (3.75)</td>
<td>7.76 (5.26)</td>
<td>9.51 (6.01)</td>
</tr>
<tr>
<td>T2 Character reading</td>
<td>0–125</td>
<td>40.46 (18.51)</td>
<td>78.12 (11.36)</td>
<td>23.86 (17.29)</td>
<td>30.79 (17.63)</td>
</tr>
<tr>
<td>T2 Radical position awareness</td>
<td>0–12</td>
<td>7.92 (2.29)</td>
<td>11.43 (1.82)</td>
<td>7.93 (1.77)</td>
<td>8.88 (1.85)</td>
</tr>
</tbody>
</table>
6.1 Development of Chinese orthographic processing.

For Chinese-English orthographic discrimination, the main effect of country was significant, \( F(1, 180) = 34.84, p < 0.001, \eta^2_p = 0.16 \). As expected, the Chinese children outperformed the Canadian–Chinese children with a \( 2 \times 2 \times 2 \) ANOVA. We examined the development of radical position awareness in Chinese and Canadian-English orthographic discrimination, and hence further analyses were performed on each group separately.

Table 2: Correlation matrix for Chinese children (left to the diagonal) and Canadian–Chinese children (right to the diagonal)

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Nonverbal reasoning</td>
<td>0.62***</td>
<td>0.55***</td>
<td>0.58***</td>
<td>0.16</td>
<td>0.37***</td>
<td>0.06</td>
<td>0.43***</td>
<td>0.23</td>
<td>0.30*</td>
<td>0.27*</td>
<td>0.12</td>
<td>0.19</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. T1 Rapid digit naming</td>
<td>0.36***</td>
<td>0.55***</td>
<td>0.44***</td>
<td>0.16</td>
<td>0.30**</td>
<td>0.12</td>
<td>0.51**</td>
<td>0.21</td>
<td>0.24</td>
<td>0.30*</td>
<td>0.19</td>
<td>0.31*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Nonverbal reasoning</td>
<td>-0.24*</td>
<td>-0.16</td>
<td>-0.29</td>
<td>-0.16</td>
<td>-0.25*</td>
<td>0.03</td>
<td>-0.18</td>
<td>0.83***</td>
<td>-0.19</td>
<td>-0.24</td>
<td>-0.08</td>
<td>0.23</td>
<td>0.08</td>
<td></td>
</tr>
<tr>
<td>4. T1 Syllable awareness</td>
<td>0.44***</td>
<td>0.49***</td>
<td>0.40***</td>
<td>0.63***</td>
<td>0.21</td>
<td>0.31***</td>
<td>0.15</td>
<td>0.43***</td>
<td>0.42***</td>
<td>0.24</td>
<td>0.29</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. T1 Phonemic awareness</td>
<td>0.50***</td>
<td>0.50***</td>
<td>0.60***</td>
<td>0.51***</td>
<td>0.32**</td>
<td>0.28**</td>
<td>0.03</td>
<td>0.35***</td>
<td>0.29**</td>
<td>0.44***</td>
<td>0.17</td>
<td>0.16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. T1 Home print exposure</td>
<td>0.44***</td>
<td>0.50***</td>
<td>0.63***</td>
<td>0.43***</td>
<td>0.55</td>
<td>-0.17</td>
<td>-0.09</td>
<td>0.28**</td>
<td>-0.21</td>
<td>0.21</td>
<td>0.21</td>
<td>0.13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. T1 Character reading</td>
<td>-0.08</td>
<td>0.16</td>
<td>0.13</td>
<td>-0.08</td>
<td>0.07</td>
<td>0.01</td>
<td>0.13</td>
<td>0.03</td>
<td>0.09</td>
<td>-0.02</td>
<td>0.05</td>
<td>0.09</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. T1 Orthographic discrimination</td>
<td>0.34***</td>
<td>0.29**</td>
<td>-0.35*</td>
<td>0.47***</td>
<td>0.41***</td>
<td>-0.04</td>
<td>0.51**</td>
<td>0.04</td>
<td>-0.20</td>
<td>0.12</td>
<td>0.17</td>
<td>0.27*</td>
<td>0.08</td>
<td></td>
</tr>
<tr>
<td>9. T1 Radical position awareness</td>
<td>-0.50***</td>
<td>-0.33**</td>
<td>-0.46</td>
<td>-0.57***</td>
<td>0.18</td>
<td>-0.58**</td>
<td>0.05</td>
<td>-0.31**</td>
<td>-0.20</td>
<td>-0.05</td>
<td>0.32**</td>
<td>0.18</td>
<td></td>
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<tr>
<td>10. T2 Rapid digit naming</td>
<td>0.54***</td>
<td>0.35***</td>
<td>-0.53***</td>
<td>0.52***</td>
<td>0.40***</td>
<td>-0.20</td>
<td>0.48**</td>
<td>0.05</td>
<td>0.32**</td>
<td>-0.56***</td>
<td>-0.52**</td>
<td>0.29*</td>
<td>0.18</td>
<td></td>
</tr>
<tr>
<td>11. T2 Syllable awareness</td>
<td>0.65***</td>
<td>0.47***</td>
<td>-0.62***</td>
<td>0.43***</td>
<td>0.84***</td>
<td>-0.38**</td>
<td>0.60***</td>
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<td>-0.58***</td>
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<td>-0.33*</td>
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<td>12. T2 Phonemic awareness</td>
<td>0.54***</td>
<td>0.48***</td>
<td>-0.66***</td>
<td>0.53***</td>
<td>0.71***</td>
<td>-0.18</td>
<td>0.87***</td>
<td>0.06</td>
<td>0.39***</td>
<td>-0.72***</td>
<td>0.56***</td>
<td>0.75***</td>
<td>0.35*</td>
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<tr>
<td>13. T2 Character reading</td>
<td>0.14*</td>
<td>0.30**</td>
<td>-0.47**</td>
<td>0.43***</td>
<td>0.57***</td>
<td>-0.20</td>
<td>0.55***</td>
<td>0.07</td>
<td>0.21</td>
<td>-0.55***</td>
<td>0.42***</td>
<td>0.63***</td>
<td>0.68***</td>
<td></td>
</tr>
<tr>
<td>14. T2 Radical position awareness</td>
<td>0.36*</td>
<td>0.30**</td>
<td>-0.47**</td>
<td>0.43***</td>
<td>0.57***</td>
<td>-0.20</td>
<td>0.55***</td>
<td>0.07</td>
<td>0.21</td>
<td>-0.55***</td>
<td>0.42***</td>
<td>0.63***</td>
<td>0.68***</td>
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</tr>
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</table>

***p < 0.001; **p < 0.01; *p < 0.05. T1 = Time 1; T2 = Time 2.
Development of Chinese orthographic processing

To examine the development of radical position awareness in the children in China, a 2×2 (Time [Time 1, Time 2]×Grade [kindergarten, Grade 1]) repeated-measure ANOVA was conducted. The main effect of time was significant, $F(1, 91)=9.43$, $p=.003$, $\eta^2_p=0.09$, and so was the main effect of grade, $F(1, 91)=54.73$, $p<.001$, $\eta^2_p=0.32$. These main effects, however, were subject to a significant time by grade interaction, $F(1, 91)=7.78$, $p=.006$, $\eta^2=0.08$. For the Chinese kindergarten children, there was no effect of time. Thus, the Chinese kindergarten children did not improve on radical position awareness from Time 1 to Time 2. For the Chinese Grade 1 children, the main effect of time was significant, $F(1, 44)=18.53$, $p<.001$, $\eta^2_p=0.30$, showing that Grade 1 children improved significantly on radical position awareness over time.

A similar 2×2 (Time [Time 1, Time 2]×Grade [kindergarten, Grade 1]) repeated-measure ANOVA was performed on the Canadian–Chinese children. We found a significant main effect of grade, $F(1, 89)=12.31$, $p<.001$, $\eta^2_p=0.12$. The Canadian–Chinese Grade 1 children scored higher on radical position awareness than the kindergarten children. There was also a significant main effect of time, $F(1, 89)=12.94$, $p=.001$, $\eta^2_p=0.12$. The interaction between time and grade, however, was not significant, $F(1, 89)=2.29$, $p=.134$, $\eta^2_p=0.02$, indicating that both kindergarten and Grade 1 children’s performance improved with time.

6.2 Factors predicting Chinese orthographic processing

A series of concurrent and longitudinal regression models were created to explore the factors that contribute to radical position awareness in the Chinese and Canadian–Chinese children. In the first three steps of all regression models, age, nonverbal reasoning, and rapid naming were entered as control variables. Syllable and phonemic awareness, character reading, and home print exposure (when applicable) were entered in the next steps. Syllable and phonemic awareness were always entered in the same step because both represented the construct of phonological awareness. We varied the order of

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**Fig. 1** Performance on radical position awareness at Times 1 and 2 as a function of country and grade

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entry of these variables in different models to determine the unique contribution of each construct to radical position awareness. The interaction between the target variable (the one that was entered after all other variables) and grade was initially included in the last step to examine whether the predictive patterns were the same for kindergarten and Grade 1 children. None of the interactions was significant ($t_s \leq 1.750$ and $p_s \geq .07$), and thus the interactions were excluded in the final regression models.

6.2.1 Predicting radical position awareness in Chinese children

Three concurrent hierarchical regressions were performed on the Chinese group to predict Time 1 radical position awareness. The first three steps were the same in all three regressions, with age, nonverbal reasoning, and rapid digit naming entered in Steps 1–3, respectively. Syllable and phonemic awareness, character reading, and home print exposure were entered in Steps 4–6 in different orders in the three regression models. As shown in the left panel of Table 3, the variables in the first three steps accounted for 20% of the variance in radical position awareness. Home print exposure did not predict unique variance when it was entered in the last step. When syllable and phonemic awareness were entered in the last step, the two variables in combination predicted 9% of the unique variance in radical position awareness. Further examination of regression coefficients showed that only syllable awareness was a significant contributor. Character reading in the last step accounted for 13% of the unique variance.

Similar concurrent regression models were calculated to predict Time 2 radical position awareness in the Chinese children. Since home print exposure was not assessed at Time 2, it was not included in these models. The results are summarized in the left panel of Table 4. Age, nonverbal reasoning, and rapid digit naming together accounted for 36% of the variance in radical position awareness. Entered in the last step, syllable and phonemic awareness combined uniquely predicted 4% of the variance. Interestingly, at Time 2, phonemic awareness rather than

<table>
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<th>Table 3 Concurrent regressions predicting Time 1 radical position awareness</th>
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<tr>
<td><strong>Steps</strong></td>
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<td>1</td>
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<tr>
<td>5</td>
</tr>
<tr>
<td>Total $R^2$</td>
</tr>
<tr>
<td>$n$</td>
</tr>
</tbody>
</table>

***$p<.001$; **$p<.01$; *$p<.05$. |
syllable awareness was a significant contributor. Character reading entered in the last step explained 13% of the unique variance.

We also computed longitudinal models using Time 1 measures as independent variables to predict Time 2 radical position awareness for the Chinese children. The predictors were the same as the concurrent models predicting Time 1 radical position awareness. The results are presented in the left panel of Table 5. In the longitudinal model, age, nonverbal abilities, and rapid digit naming in the first three steps accounted for 29% of the variance in radical position awareness. Entered in the last step, home print exposure was not a significant predictor; syllable and phonemic awareness did not predict a significant amount of variance either. In contrast, character reading accounted for 5% of the unique variance in radical position awareness.

6.2.2 Predicting radical position awareness in Canadian–Chinese children

The Time 1, Time 2, and longitudinal regression models predicting radical position awareness in the Canadian–Chinese children followed the same steps as the corresponding models in the Chinese children. The Canadian models are displayed in the right panels of Tables 3–5. As shown in the right panel of Table 3, when predicting Time 1 radical position awareness in the Canadian group, age, nonverbal reasoning, and rapid digit naming in the first three steps accounted for 31% of the variance. In the last step, only home print exposure added 3% of the variance in the model. Neither the two phonological awareness measures nor character reading explained unique variance in radical position awareness in the last step.

The concurrent models with Time 2 radical position awareness as the outcome variable are presented in the right panel of Table 4. Home print exposure was not part of these models because it was evaluated at Time 1 only. Together the variables in the first three steps explained 16% of the variance in Time 2 radical position awareness. Entered in the last step in separate models, the phonological awareness measures did not explain unique variance at Time 2, whereas character reading uniquely predicted 10% of the variance.

In the longitudinal models (the right panel of Table 5), age, nonverbal reasoning, and rapid digit naming in the first three steps accounted for 8% of the variance in total. Time 1 home print exposure uniquely predicted 10% of the variance in Time 2 radical position awareness in the last step for the Canadian–Chinese children. Neither character
reading nor the phonological awareness measures were significant predictors in the last step.

7 Discussion

This study investigated the development of orthographic processing in the early stages of Chinese literacy acquisition, and whether and to what extent home print exposure, character reading, and phonological skills predict Chinese orthographic processing skills. We carried out the investigation in China and Canada to examine the effect of language learning context on the development of orthographic processing. In the following sections, the results are discussed separately for the questions of how children develop Chinese orthographic processing skills and what factors contribute to the development of such skills.

7.1 How do children develop Chinese orthographic processing skills?

As expected, the Chinese children showed a higher level of radical position awareness than the Canadian–Chinese children. This is the natural result of their respective language learning environments. For the Chinese children, Chinese was the dominant language of the society, as well as the language used at school and home. For the Canadian–Chinese children, Chinese input was quite limited. It mainly consisted of Chinese language use at home and 2.5 h of Chinese heritage language program every week. Notably, the difference in language input led not only to different levels of performance on radical position awareness, but also to different developmental trajectories in the two groups of children.

In China, the kindergarten children did not improve on radical position awareness from Time 1 to Time 2, while the Grade 1 children showed significant growth overtime. The kindergarten and Grade 1 children differed in the type of literacy instruction they received. The kindergarten children were engaged in informal literacy activities that focused primarily on oral language proficiency, whereas the Grade 1 children received systematic instruction in both oral and written language. It is worth noting that, despite a lack of formal instruction, the kindergarten children demonstrated rudimentary sensitivity to radical positions—their performance...
Development of Chinese orthographic processing

7.2 What factors contribute to the development of Chinese orthographic processing skills?

To our knowledge, this was the first study to investigate the factors contributing to the development of orthographic skills in Chinese reading research. In light of previous research on orthographic processing in alphabetic writing systems (e.g. Stanovich and West, 1989; Barker et al., 1992; Ehri, 2005; Castles and Nation, 2006) and the characteristics of the Chinese writing system, we identified home print exposure, phonological awareness, and character reading ability as three potential factors that may explain the variance in Chinese radical position awareness. Our results suggest that these three factors play different roles in the orthographic processing in Chinese children and Canadian–Chinese children.

For Chinese children, measures of phonological awareness were significant concurrent predictors of orthographic processing. In particular, syllable awareness predicted unique variance in radical position awareness at Time 1, while phonemic awareness was a unique predictor at Time 2. Phonological awareness has been shown to predict character reading (e.g. Ho and Bryant, 1997a, b; McBride-Chang and Ho, 2000, 2005). Our findings suggest that it also plays an important role in Chinese orthographic processing. Phonological and orthographic features are interrelated in Chinese (Feldman and Siok, 1997; Chan and Nunes, 1998). The phonetic radical in a semantic–phonetic compound conveys information about the character pronunciation, e.g. 青 qing1 青 qing1, and the phonetic radical typically appears on the right side of a compound character. This dependency may explain why phonological awareness contributes to orthographic processing in Chinese. However, this explanation can only be tentative and needs to be confirmed by future research because we did not explicitly investigate children's knowledge of semantic and phonetic radicals in the present study. It is worth noting that neither phonological awareness measure predicted orthographic processing longitudinally in our study. The lack of
longitudinal prediction indicates that the association between phonological awareness and orthographic processing is relatively weak in Chinese, due to the fact that the mapping between phonology and orthography is not systematic.

Character reading was the strongest unique predictor of radical position awareness for the children in China. In this group of children, the number of characters read correctly accounted for unique variance in Chinese radical position awareness concurrently and longitudinally after partialling out the effects of other variables. The significant concurrent and longitudinal relationships reveal that character learning is a driving force for the development of awareness of radical positions. With a larger character repertoire, the child has a better chance of abstracting orthographic regularity of radical positions. Our findings are in line with a recent suggestion pertaining to the relationship between word reading and orthographic processing in English (Ehri, 2005; Castles and Nation, 2006). That is, more capable readers may have more heightened awareness of legitimate spelling patterns in English. A similar reciprocal relationship is likely to exist between orthographic processing and reading in Chinese.

The Canadian–Chinese children demonstrated different predictive patterns of orthographic processing compared with the Chinese children. For the Canadian group, the phonological awareness measures did not predict unique variance in radical position awareness either concurrently or longitudinally. These children's understanding of the functionality of semantic and phonetic radicals was yet to develop in kindergarten and the early grades, and therefore phonological awareness was not associated with orthographic processing during this period of time. With respect to the prediction of character reading to radical position awareness, the only significant relationship was observed at Time 2. The lack of significant relationships at Time 1 and longitudinally may be due to the fact that the Canadian–Chinese children, especially the kindergarten children, scored very low on character reading at Time 1. As such, their character knowledge was not strong enough to sustain growth in radical position awareness. As the Canadian–Chinese children's character reading ability increased over time, the relationship with radical position awareness also strengthened.

The patterns of relationships were also different in the two groups of children regarding the role of home print exposure in radical position awareness. Home print exposure was a significant predictor of radical position awareness in the Canadian–Chinese children, explaining unique variance at Time 1 and longitudinally. By contrast, home print exposure was not correlated with radical position awareness among the children in China. The findings concerning the Canadian group lends support to the important role of print exposure in the development of orthographic processing discovered in English readers (Stanovich and West, 1989; Cunningham and Stanovich, 1990; Stanovich et al., 1991), suggesting that, across different writing systems, repeated exposure to written texts can be a source of acquiring and strengthening orthographic representations.

In China, however, home print exposure does not fully capture the amount of exposure to written Chinese because children also have ample opportunities to learn print at school. For Chinese children, the effect of home print exposure appears to be small in comparison to factors related to school instruction, such as character reading and phonological awareness. It should be noted that a recent study by Lin et al. (in press) reported a significant correlation between shared mother–child writing (which may be interpreted as another aspect of home print exposure) and orthographic processing in Hong Kong Chinese kindergartners. Thus, while home exposure to reading as measured in the present study is not significantly related to orthographic processing skills in children who receive intensive formal literacy instruction in school, home exposure to writing may still be an important contributor. However, since Lin et al. (in press) only examined the correlation between shared writing and orthographic processing, it is not clear whether the former will remain to be a significant predictor of the latter after controlling for other reading related variables. This issue needs to be explored by future studies. In sum, the different patterns of results between Chinese children and Chinese–Canadian children highlight the impact of language learning environment on the development of literacy skills.
8 Limitations and Future Directions

Our study has several limitations that need to be addressed by future research. First, the reliability of the radical position awareness measure was relatively low, particularly at Time 1. The low reliability observed at Time 1 may reflect young children's unstable representation of orthographic patterns before receiving formal school instruction in reading. A related issue is that the correlation between the performance on the radical position awareness task at Time 1 and that at Time 2 was not significant in either the Chinese children or the Canadian–Chinese children. It is not entirely clear why the scores were not correlated between the two testing times, though at both testing times, the radical position awareness measure was significantly correlated with character reading. Orthographic processing, a print-based skill, improves rapidly in the first few years of school once children start receiving literacy instruction. In our study, with the exception of Chinese kindergartners, children experienced significant growth in radical position awareness from Time 1 to Time 2. The increase in orthographic understanding may to some extent reduce the correlation between the two testing times. Because of these limitations, the results of the present study should be interpreted with caution and should be replicated with more reliable measures of orthographic processing in future research.

The present study is also limited in the scope of orthographic processing that it examined. We focused on radical position awareness without considering the functions of semantic and phonetic radicals. As previously noted, radical position is related to function, e.g. a semantic radical tends to appear on the left side of a compound character (Feldman and Siok, 1997; Chan and Nunes, 1998). Future research should explore awareness of radical position and function in the same study. Another limitation is the number of predictors included. Although we successfully identified three predictors of Chinese orthographic processing, our regression models accounted for about 50% or less of the total variance in radical position awareness. Future research need to consider other potential predictors of Chinese orthographic processing, such as visual perceptual skills and morphological awareness. Visual perception is the prerequisite for orthographic processing. Morphological awareness, phonological awareness, and orthographic processing may be intricately related in Chinese due to the fact each character represents one morpheme and maps onto one syllable in the oral language. Finally, in the present study, we were only able to explore the effect of character reading on orthographic processing. Future studies need to empirically test the bidirectional relationship between orthographic processing and character reading with a larger sample and multiple time points.

To summarize, the present study clearly demonstrates similarities and differences in the development of Chinese orthographic processing in a Chinese-dominant language learning context and in a context where Chinese is a minority language. One similarity is that both Chinese children and Canadian–Chinese children develop the ability to differentiate orthographic units in English and Chinese at a very early age. However, there are also important differences between the two groups of children, reflecting the impact of language learning environment. Generally speaking, children in China develop more advanced radical position awareness than their counterparts in Canada, due to greater and more systematic Chinese exposure. Our study also shows that different factors contribute to individual differences in Chinese orthographic processing in different learning environments. In China, phonological awareness and character reading, both closely related to school instruction (e.g. Korkman et al., 1999), are most prominent factors, whereas in Canada, home print exposure contributes the largest amount of variance.

Our results have practical implications, particularly for Canadian–Chinese children. The development of orthographic processing among this group of children seems to be more dependent on home print exposure. This to some extent implies that the limited amount of instruction they receive in heritage language programs is not sufficient to sustain the development of Chinese orthographic processing skills. Therefore, in order to produce bilinguals...
proficient in both English and Chinese in the Canadian context, it is necessary to increase the amount of Chinese instruction received by Canadian–Chinese children. Furthermore, since Canadian–Chinese children lag behind their Chinese peers in the development of orthographic processing, they may require more explicit instruction on the orthographic structure of Chinese characters. This possibility warrants future research. Finally, our results underscore the importance of home print exposure to Chinese in a language learning context where Chinese is not the majority language, suggesting that parents of language minority children can play a key role in their children's first language and literacy development.

Acknowledgements
The authors wish to thank Dr. Charles Perfetti for his advice on the research. They thank their research assistants for help with data collection and entry. They also thank the participating students, parents, and teachers.

Funding
This research was supported by grants from the Social Sciences and Humanities Research Council of Canada awarded to X.C. and Y.C.L.

References


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